

# THE ANALYSIS OF FAUNAL REMAINS FROM THE VIDOR SITE

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## ABSTRACT

*Excavations in 1973 at the Vidor Site yielded large quantities of faunal remains. The data presented here focus on the Middle Polychrome Period, and indicate significant changes in the frequency of occurrence of various species of fish and animals. Possible cultural and natural variables are examined, and some of the seasonality data presented by Moreau are discussed.*

## RESUMEN

*Durante las excavaciones de 1973 en el sitio Vidor se recuperó gran cantidad de huesos de animales terrestres y marinos. Los datos que se presentan aquí corresponden a los restos del período Policromo Medio, y muestran cambios significativos en la frecuencia de especies individuales. Se revisan las posibles variables culturales y naturales, y se comentan algunos de los datos presentados por Moreau referentes a los cambios estacionales.*

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## Introduction

The Vidor Site (30471-227-1) is located about 1 km inland from Playa Panama, near the mouth of the Bay of Culebra. The shell middens at the sites, although defined on the basis of their prominent molluscan contents, also contain significant amounts of ceramics, lithics and vertebrate remains, such as are discussed here. Sedimentary deposits include volcanic ash and alluvium, the latter derived from slope wash caused by seasonally heavy rains, and periodic floodplain inundation. Two volcanic ash deposits are found separating the Middle Polychrome Period into early (AD 800-1000) and late (AD 1000-1200) phases. The earliest deposit is thicker, ranging from 15-25 cm. This stratigraphic association suggests at least a temporary abandonment and resettling of the site (Accola 1978a; Lange 1978b).

## Methods

Data reported on in this paper were excavated in 1973 and 1976. In 1973, Mounds I and II were sampled with 1/2" screen, while, with the exception of one column, the 1976 excavations (Mounds A and B) were sampled with 1/4" screen. The difference in screen sizes was dictated by rainy season conditions, when clayey mud will not pass through a 1/4" screen.

Deficiencies resulted from the use of 1/2" screen, as seen in Table I summarizing fish data aggregated by habitat groups. In comparing the large Early Middle Polychrome (EMP) samples, the pelagic fauna (99% tuna, c.f. *Euthynnus lineatus*) show a significant jump in MNI (Minimum Number of Individuals) percentage between 1/4" and 1/2" screen: 15% to 36%; by contrast, the "Caranx" group (18% to 5%) and the "Unidentified Fish" group (20% to 7%) decline. Many of the *Caranx* remains are attributable to *Caranx caballus*, a small fish, whose diagnostic third to last vertebrae, frequently used in the *Caranx* MNI counts, pass through the larger screen. The "Unidentified Fish" MNI counts are based on number of vertebrae (37 per MNI, an arbitrary ratio) which, due to their generally small size, accounts for their lowered percentage. Other fish (*Scarus*, *Bodianus*, *Diodon*) have MNI counts based on larger mouth and skull parts and their MNI figures do not vary. This reveals the pitfalls in data comparisons from differentially excavated materials. The obvious increase in the pelagic MNI percentage within the Middle Polychrome would not be picked up in comparisons between Early Middle Polychrome 1/2" screened and Late Middle Polychrome 1/4" screened samples (36% vs. 35%).

Where possible, fish were grouped according to preferred habitats, with groupings based on several sources: personal experiences with fish procurement at Playa Panama, and several

references (Randall 1968; Miller 1954, 1966; Meek and Hildebrand 1923, 1925; Follett 1967; Fitch and Lavenberg 1975 and Baily *et al* 1970). No general sources are available on the ecology of tropical Eastern Pacific fish, and the information must be acquired for individual species. This was done in the field for most common fish, and correspondence with Dr. R. Rosenblatt of Scripps Institute of Oceanography refined the designations. These designations are intended to be conservative and include only fish generally restricted to a given habitat. Three groups, pelagic, reef/rock and estuary, are well defined, while the group "Estuarine Tendency" is less clear cut since these fish also occur in other inshore habitats, especially those with sandy substrata. Other authors (e.g. Follett 1967) would characterize many of these species (c.f. *Elops affinis*, *Lutjanus*, *Mugil*, *Siluriformes*) into estuarine niches. Though habitat attributions were not possible, two (*Caranx*, *Diodon*) groups were established in Table I due to the abundance of the remains.

Data for avian, mammalian and herpetofaunas are summarized in Table III. For purposes of environmental discussions, only locally procured and eaten terrestrial species are included. The data excludes the following tetrapods: *Homo sapiens*, microfauna (small rodents and anurans), domestic species (dog, turkey), marine turtles, bats and non-terrestrial foraging birds. The effect of these omissions on the analysis is negligible.

### General Notes on the Archaeological Faunas

The archaeological ichthyofauna contrast with Leon's (1973) discussion of the fish of the Gulf of Nicoya, where the Tempisque River discharges. There, the estuarine environment is dominated by Sciaenidae (especially *Stellifer sp.*), which have not been conclusively identified from Playa Panama. At Playa Panama, estuarine fish do occur in the archaeological sample from Vidor, but they do not dominate the fauna, in contrast with generalizations such as:

It is these estuaries that are the richest source of fish, as I can testify from experience, and I consider it likely that practically all fishing was carried out in these rather than in the open sea which is usually choppy to rough due to strong sea and land breezes (Coe 1962a).

In their summary article on Mesoamerican Pacific coastal adaptations, Hubbs and Roden (1964:181) wrote that rich coastal lagoons and estuaries were exploited; they stated, moreover that "We have not encountered evidence that the coastal natives took advantage of the great offshore abundance of tuna". Pelagic fauna are abundant at the Vidor site (Table I), despite the accessibility of several estuaries within the Bay of Culebra; one, Estero de Iguanita, is of large size. This evidence does not necessarily imply that a complex technology was required to procure tuna, for small tuna are captured within the bay today. It also is not necessary to postulate development of offshore fishing industries to procure the scombrid species represented here. Most previous interpretations of prehistoric subsistence practices along the Mesoamerican-Central American Pacific coast have not even speculated on the possibility and potential of marine fishing on the open seas. This report represents an initial discussion of data reflecting such activities.

As a whole, the terrestrial fauna in the Vidor cultural sequence indicate conditions much the same as today. Species which may not have been eaten, but which are especially adapted to the seasonally dry environment in Guanacaste include the cotton rat (*Sigmodon hispidus*), the spiny pocket mouse (*Liomys salvini*) and the anuran (*Rhin dorsalis*). Both the iguanid (*Ctenosaura*) and the rattle snake (*Crotalis durissus*) are currently confined to dry northwest Costa Rica. To a lesser extent this is also the favored environment of *Constrictor constrictor*. Two species of birds are characteristic of Sludd's (1964) arid Pacific avifauna, the bobwhite (*Colinus leucopogon*) and the dove (*Zenaida asiatica*).

Among modern mammals, the rabbit (*Sylvilagus floridianus*) is confined to Guanacaste, and the armadillo (*Dasyus novemcinctus*), whitetail deer (*Odocoileus virginianus*) and agouti (*Dasyprocta punctata*) prefer conditions found there, though they are by no means confined to the area. Certain species are notable in their absence or paucity in the archaeological data. The rainforest oriented brocket deer (*Mazama americana*) and tapir (*Tapirus baird*) are represented by two and one bones respectively, the latter by a pierced tooth of possible ritual or commercial value.

## Discussion

Knowing the orientation of any faunal analysis is critical for evaluating the validity of the interpretations. While in some cases data may conclusively indicate subsistence change through time, the discussion of the subsistence behavior of a population at a given point in time is more precarious. Post-depositional disturbance, selective weathering, excavation techniques, stochastic effects and intrasite cultural differences contribute to distortion of data used in synchronic subsistence analyses. "Cultural differences" include specific food processing localities, the agent of refuse deposition (dog, commoner, aristocrat), and seasonal site habitation. Assuming some of these distortions remain constant through time, a diachronic analytical approach controls, but does not eliminate, certain biases, such as the effects of the 1/2" screening discussed earlier. Despite the skewed results, changes through time are reflected in the data recovered from 1/4" screen (discussed more fully below). Even with these cautions when suggestions of changes in subsistence activity through time are seen in data at a given site, one may *hypothesize* possible causative phenomena, and the roles of environment and/or cultural agents.

## Brief Overview of the Data

In a diachronic approach, data are discussed as they remain constant or change through time, and cannot be discussed in absolute terms, as the data bases for different time periods are frequently disparate. Ratios, and percentages must be employed, and this, in turn, is effective only if the ratios and percentages are based on large samples.

The crudest level of analysis for the Vidor data is to contrast marine and terrestrial fauna. As the data from Tables IV-XI indicate, the archaeological faunal samples from the Early and Late Polychrome periods are not satisfactory for analysis. The 1/2" screen samples are skewed and should be viewed with caution. A smaller sample size aligns the Early Polychrome period with the Early Middle Polychrome period (Tables V, IX), while the Late Polychrome period approximates the Late Middle Polychrome (Table IX). The best faunal samples from the site are the two Middle Polychrome (Early Middle Polychrome, Late Middle Polychrome) 1/4" components (Tables IV-VII). Table IV indicates that while the terrestrial component remains relatively constant between Early Middle Polychrome (1/4") and Late Middle Polychrome (1/4") times (22 vs. 24 MNI), the numbers of fish exhibit a three-fold increase. This does not mean that the terrestrial component fails to contribute a major percentage of the protein, since a dressed-out deer yields well over 100 times the meat weight of various smaller fish species. We may ask, which fish, if any, are responsible for this increase between the Middle Polychrome phases?

Table I indicates the percentages of fish recovered from various habitats. Within the fish category, the pelagic fauna (99% *c.f.* *Euthynnus lineatus*) show a considerable increase in the 1/4" Middle Polychrome sample from 15% to 35% of total fish MNI. The other significant change within the marine habitat statistics is the decline of the estuarine (broadly defined) groups, dropping from 7% to 3%; the "estuarine tendency" group also drops from 14% to 6%. Composite totals drop from 21% to 9%; while this suggests that the "estuarine tendency" group has habitat significance, the estuarine groups are relatively constant relative to the terrestrial fauna (Table VII). The pelagic fish obviously show the greatest increases relative to the terrestrial fauna (Table V), with a greater than seven-fold increase in ratios. As a whole, the non-pelagic ichthyofauna increased 2 1/4 times relative to terrestrial fauna (Table VI).

Interestingly, comparable results were obtained from the 1/2" screen samples (Tables VIII-XI) regarding ratios between terrestrial fauna and both the total fish count and the pelagic fish (Tables VIII and IX). This is in part due to the retention of large caudal tuna vertebrae used in the MNI counts, and absolute decreases in the terrestrial fauna, much of which should be retained in the 1/2" screen. In contrast, the ratio of terrestrial fauna to non-pelagic (non-tuna) fish does not change significantly (Table X). This is due, in large part, to the loss of the relatively small fish vertebrate used to make up the MNI counts for the "unidentified fish" group and *Caranx sp.* Together, these two groups comprise 38% of the Early Middle Polychrome and 39% of the Late Middle Polychrome ichthyofaunal samples from the 1/4" screen samples, while in the 1/2" screen samples their values are only 12% (EMP) and 8% (LMP). Again, Early Polychrome and Late Polychrome affinities are with the respective adjacent Middle Polychrome phase.

Though the percentages are greatly skewed in favor of the pelagic fish (especially relative to *Caranx sp.* and "unidentified fish") in the 1/2" sample (Table I), diachronic analysis eliminates some difficulties in interpretation. As in the 1/4" screen samples, pelagic fish show more than a two-fold percentile increase (36% to 75%, Table I), and the two estuarine samples are again nicely complementary, declining from 25% to 3% from Early Middle Polychrome to Late Middle Polychrome (7% to 2% for the estuary group, and 18% to 1% for the "estuarine tendency" group). The skewing effects of the tuna cause decreases for all other fish groups in the 1/2" samples, being greatest in the estuary groups.

The two dominant faunal species, *Odocoileus virginiana* and *c.f. Euthynnus lineatus*, reflect these basic differences. The use of deer as a "terrestrial fauna" indicator is important in several respects. In terms of meat weight per individual, deer are dominant species. Whereas deer are represented by more than 100 elements in each Middle Polychrome phase (for both 1/2 and 1/4" samples), other mammals are often represented by 1-5 elements (Table III), and the relative contribution of such species to an assemblage is disproportionately increased. The small sample sizes in Late Polychrome and Early Polychrome components might tend to disproportionately represent terrestrial faunas, since deer bones are not affected by screen size. Irrespective of screen size, the data below show a strong correlation in the ratio between tuna MNI and total number of deer bones. The large Middle Polychrome samples illustrate this. In the Early Middle Polychrome 1/4" sample the ratio is 1 (tuna MNI) per 9.9 deer bones (Table IV), while in the Early Middle Polychrome 1/2" sample the ratio is 1:9.2. For the Late Middle Polychrome, the respective figures are 1:1.6 and 1:1.8; the data indicate that for these specific ratios, screen size has little or no effect. This in turn causes the Early Polychrome and Late Polychrome samples to be more comparable to those from the Middle Polychrome. Based on these ratios, the 1/4" Early Polychrome sample can be added to the 1/2" Early Polychrome sample, resulting in a sufficient data base for comparison throughout that part of the cultural sequence at the sites for which there are faunal remains. As Lange has pointed out elsewhere in this volume, faunal remains were not preserved in association with Zoned Bichrome levels, and are present only in Early, Middle, and Late Polychrome components. These results suggest continuities between the Early Polychrome and Early Middle Polychrome phases, and also between the Late Middle Polychrome and Late Polychrome phases (see Table IV).

### Interpretations

Numerous hypotheses can be proposed to account for the differences outlined above. Among them are:

1. seasonal differences in food procurement;
2. technological innovation;
3. demographic effects of increased terrestrial exploitation;
4. environmental effects of volcanic ash deposits.

A more detailed examination of these four possible interpretations yields a better understanding of the role each may have played in causing the observed differences.

*Seasonal differences in food procurement:* Seasonal shifts in available fauna, coupled with seasonal site habitation, might be factors in faunal changes. Evidence suggesting year-round site occupation includes some indications of agricultural techniques, a fishing industry, and kilns and habitation floors. Other direct evidence of relevance is that the two species which contributed the bulk to the animal protein are most readily exploitable during the dry season. During this time of year, seasonal streams disappear, deer frequent springs and concentrated vegetable resources, and high winds dissipate the hunters' scent; these represent optimal hunting conditions, and even today deer hunting efforts are concentrated in the dry, windy season.

These same winds are responsible for the availability of pelagic tuna, whether *Euthynnus lineatus* or other species. The seasonal winds from November-April (Vivó Escoto 1964) create upwellings favoring exchange of nutrients from ocean substrata to more superficial levels. Nutrient exchanges at the lowest trophic level serve as the basis for tuna predation at the surface.

On the basis of extensive molluscan analysis of a nearby single component "inland" Late Polychrome site, Moreau (this volume) suggests seasonal nine month habitation. He speculates

that the three month rainy season may have been spent on the coast to take advantage of marine resources. This is not consistent with the scanty data of the vertebrate fauna from the Late Polychrome period. Maximum availability and exploitation of tuna, which dominate the skewed Late Polychrome sample, would have occurred during the dry season.

*Technological innovations:* Maritime adaptation, and participation in coastal trade networks, might have stimulated technological innovations which also facilitated the exploitation of pelagic resources. The only direct archaeological evidence is hypothesized net sinkers, dating back to at least the Early Polychrome Period (Lange 1971a, 1971b; Stone 1977). Notched sherds are also found and their use as gauges for standard width dimension in the manufacture of fish nets has been suggested (Lange 1971b). There is no evidence, however, to indicate the netting of pelagic fish.

Contemporary Ecuadorian and Peruvian Indians catch *E. lineatus* in surface waters from simple canoes and rafts (Calkins and Witold 1963); techniques include live bait, poles and lines, trolling gear and purse seines. As discussed earlier, it is not necessary to postulate introduction of sophisticated offshore fishing techniques for the procurement of pelagic tuna, especially since these fish are readily available in the sheltered waters of the bay. The strongest argument against any major technological innovation is that tuna were procured from Early Polychrome times on, and were always a significant component of the diet.

*Demographic effects to increased terrestrial exploitation:* Lange (1978a, b and this volume) discusses a shift towards coastal settlement and maritime adaptation in northwest Costa Rica beginning in Early Polychrome times. Although some coastal sites have Zoned Bichrome components, only during the Early Polychrome period did intensive exploitation of marine resources begin. Subsistence data reflect the first exploitation of molluscan fauna, as well as the subsequent trends toward marine vertebrate exploitation documented in this paper. Though Early and Middle Polychrome sites are found in inland areas, the majority of sites with components from these periods are concentrated near coastal habitats. Furthermore, during the Late Polychrome Period, nearly all sites are concentrated on the northern Pacific coast. This contrasts with the Nosara Valley of the Nicoya Peninsula to the south, where there are no Late Polychrome components at any of the 28 surveyed sites, despite an abundance of Middle Polychrome remains (Lange *et. al.* 1976). Lange points to the absence of molluscan colonies on the southern coast as one possible factor influencing settlement shifts. Abel-Vidor and Lange, in other articles in this volume, discuss additional aspects of settlement, subsistence and political-economic change in the region during the Late Polychrome period.

Elsewhere, Lange (1978b:113) suggests possible destruction of habitats of terrestrial resources as a result of increasing coastal populations; this seems unlikely. For example, *Odocoileus virginianus* was typically the most desired terrestrial game in precolumbian lower Central America, and remains of this species provides the majority of the terrestrial meat at Playa Panama. Archaeological evidence for *Odocoileus* is also described in Cooke (1978, Pacific Panama), Healy (1974, southwest Nicaragua), and Sweeney (1975, northwest Costa Rica). The ability of the white-tailed deer to coexist with man is well documented, and Cooke (1978), in discussing precolumbian deer dependency over a 7000 year period in climatically similar habitats of Pacific Panama (seasonal drought, deciduous scrub forest), cited several appropriate sources (Bennett 1968; Carbaugh *et. al.* 1975). Cooke (1978:6) also observed that:

agriculturalists, by the very modification of forest habitats, are likely to exploit heavily, not the species left in the well-wooded areas or hard to reach canopies, but rather those which, moving into disturbed plots attracted by the abundance of food and shelter, increase greatly their biomass.

Ruben Reina (1967) also commented on the relationship between *milpa* clearings and deer hunting among the lowland Maya.

The excavated data from Vidor do not really suggest over-exploitation. Assuming the Early Middle Polychrome and Late Middle Polychrome phases represent comparable periods of accumulation, terrestrial faunas, including deer, remain fairly stable in *absolute* terms between Early Middle Polychrome and Late Middle Polychrome phases; it is an increase in marine faunas that accounts for a *relative* decrease in terrestrial fauna. Intensified fish extraction efforts might be expected to accommodate greater populations while previous hunting efforts were maintained or ritually limited (see Cooke 1978). Lange (1971b, 1978a,b) has repeatedly emphasized the agricultural limitations of the area, questioning increased

subsistence efforts by these means.

*Environmental effects of volcanic ash deposit:* Moreau (1978) was the first to suggest an association between the volcanic ash deposits and subsistence behavior. Extensive molluscan data indicated significant increases in intertidal bivalves, especially *Chione subimbricata*, over shallow water molluscs, especially *Anadara multicostata*, following volcanic eruptions. Intertidal waters are warmer and more saline than shallow waters, and salt elements, characteristic of many volcanic ash falls, might be expected to increase the salinity of both the intertidal and shallow water zones. Sea temperature might also be expected to rise, and Moreau theorized that intertidal increases in salinity and/or temperature would influence resident molluscan faunas, causing them to migrate to shallower waters matching their previous ecological requirements. Shallow water forms would thus migrate to deeper waters, where they would not be as easily exploited for subsistence.

Though intriguing, there are major drawbacks to Moreau's assumptions: 1) Sedimentary evidence from the ash deposits indicating the salt composition is required to confirm or refute Moreau's thesis; 2) Standing alone, the molluscan data might reflect seasonal procurement with increases in inshore salinity occurring in the dry season; 3) Such an ash fall might prove fatal to all inshore filter feeders; and 4) such homeostatic molluscan migrations are purely hypothetical.

Based on fragmentary data, one can estimate the relatively short term effects of a 20 cm ash fall as indicated at Playa Panama. The following hypothetical scenario might be representative: Due to the distance from the volcanic sources, ash depth and the location of Playa Panama, there is a good possibility the ash was deposited during the windy dry season. Upland erosion would be rapid with the onset of the rainy season, while low lying alluvial plains were less likely to have been eroded. Deposits of ashbearing alluvium would settle as streams lost their gradient on floodplains and estuaries. Therefore, flooding and mud flows would have been likely during the first rainy season (Segerstrom 1950, 1966; Wilcox 1959; Eggler 1949; Taylor 1957). Cultivated areas of low topographic relief are severely affected, and would take the longest time to recover (Griggs 1915, 1918; Eggler 1948, 1963, 1967), and agricultural produce would not be available for some time thereafter. Wind-blown ash immediately strips all vegetation (Gates 1914; Griggs 1915, 1918), rupturing the terrestrial trophic levels at their source. Terrestrial fauna either leave or perish (Malde 1964), and pelagic fish momentarily move to deeper and/or less affected waters, but soon return (Porarinnsson 1954). Terrestrial recovery by grasses is rapid, within months, and serves as a foundation for future re-vegetation (Griggs 1915, 1918; Eggler 1949). The recovery of terrestrial fauna lags behind terrestrial flora by an unknown interval, although deer and other animals were seen to rapidly re-enter the area affected by the recent Mt. St. Helen's eruptions.

In light of Moreau's discussions of marine mollusc patterns, it is tempting to view the Vidor site pattern of vertebrate fauna as complementary. Thus, in response to a major volcanic eruption and deposition, subsistence behavior is modified, and there is greater emphasis on marine exploitation, especially pelagic fish which appear to have been the least affected subsistence component. Marine productivity may in fact be enhanced, despite temporary reduction in solar radiation created by a floating ash blanket. Settling and dissolution of the ash may provide key nutrients for phytoplankton, the foundation of the marine food chain (Buljan 1955). Above all, we must remember that the effects of eruptions vary greatly, from one to the next, as demonstrated by the research directed by P. Sheets in El Salvador (Sheets 1978).

During the Late Middle Polychrome Period, only one of the ichthyofaunal components did not increase relative to the terrestrial fauna: the estuarine group(s) (Table VII). These fish might be the most likely marine component to be affected by the ash fallout, concentrated in particulate and dissolved form, in continental run-off. If, as Moreau suggested, the ash increases the salinity of the waters, the brackish water estuaries would be hardest hit due to high ash concentrations, contrasted with relatively low pre-ash fall levels of salinity, characteristic of brackish estuarine waters.

The greater mobility of pelagic versus inshore fish, as well as the fact that ash is deposited in much deeper waters and is less concentrated, guarantees the maintenance of locally available populations. The relatively mobile species of *Caranx* (*hippos*, *caballus*) would be little affected, as they occur in both inshore and pelagic contexts; these fish show absolute increases second only to the pelagic tuna between Early Middle Polychrome and Late Middle Polychrome times (Table I).

Finally, the suggested associations between Early Middle Polychrome and Early

Polychrome, and between Late Middle Polychrome and Late Polychrome indicate a rapid change in subsistence behavior at the Early Middle Polychrome/Late Middle Polychrome interface versus a more gradual transition. This would be a predicted outcome of a catastrophic event, unlike the "over-exploitation" model which implies a gradual thinning of local game.

Though provocative, there are two major problems with these arguments:

1) Undoubtedly there was an immediate effect on local terrestrial populations by ash falls of the magnitude seen at the Vidor site, but there is no available archaeological evidence to document the recovery of these populations. Recovery might occur within a decade, and given evidence indicating the length of the Late Middle Polychrome phase as about 200 years, complete recovery could have occurred early in the phase. The possibility of site abandonment immediately after the ash fall, reflected in the ceramic unconformity (Accola 1978a), suggests that resettlement might not have occurred until some environmental equilibrium had been re-established. Furthermore, the fragmentary evidence suggests that the Late Polychrome Period represents a continuation of the Late Middle Polychrome phase subsistence strategies, although it is quite possible that terrestrial faunas had recovered by this time.

2) In *absolute* terms the terrestrial fauna did not greatly decrease. If comparable time periods and populations are represented by the two Middle Polychrome phases, then absolute increase in fish might simply be compensation for lost agricultural production. The loss of this production might account for the noted faunal concentrations immediately overlaying the ash layer (Moreau 1978; Honetschlager *et al.* 1976). Only if the Late Middle Polychrome phase represented a longer time span, with relatively constant populations, can the increase in marine resources be interpreted to be "at the expense" of the terrestrial faunas.

Sheets (1977) has incorporated elements of such a volcanic scenario to account for regional settlement shifts following the C. AD 250 eruption of Ilopango in El Salvador. As in Sheets' case, the shifts in settlement pattern discussed by Lange (1978a, b) reflect shifts away from central highlands of the Cordillera Central, as well as from the broad, low-lying alluvial plain of the Tempisque River. The latter would be most susceptible to immediate flooding and mud flows, and the highlands are the very locations of the volcanos' activity. Though erosion would be rapid on the sloped surfaces, the immediate effects of voluminous volcanic ejecta would be devastating. Perhaps, therefore, inland volcanism was a factor in stimulating coastal settlement patterns in northwest Costa Rica during Middle and Late Polychrome times.

### Future Research Objectives and Summary

A preliminary discussion of this style provides no definitive answers. A regional perspective is necessary, and the papers in this volume provide substantial foundations. Though this paper is deterministic, the following research objectives may help to resolve various questions which have surfaced in the preceding discussions. Isolated, as well as multiple-causative phenomena, should be considered:

#### 1) Sediment Analyses.

a) Determination of degree of ash layer weathering would indicate whether or not the site was abandoned during or after the ash fall, and may provide evidence indicating the length of abandonment;

b) A geochemical analysis of the ash is necessary to determine potential salinity and nutrient content. It might also provide evidence of plant/animal toxicity in regard to fluorides, acids and other chemical residues;

c) Analysis of the alluvial sediments both at Playa Panama and in the Tempisque and Nosara River (farther south on the Nicoya Peninsula, somewhat more distant from the volcanic chain and thus of comparative value) drainages would determine their relation, if any, to ash deposits; and

d) A phytolith study would provide hard evidence for pre-and post-ash fall agricultural practices, as well as floral succession and recovery.

2) Sex and age analysis of a large sample of deer remains might provide evidence for over-exploitation during Middle and Late Polychrome times.

3) If C14 dating is sufficiently precise, determination of the relative length of the two Middle Polychrome phases is possible. This is of value in estimating the worth of relative ratios versus absolute numbers in interpreting subsistence changes.

4) The areal extent of the ash fall must be determined, and a regional picture of subsistence practices based on comparable faunal samples should then be accumulated. For example:

a) Data presented here must be compared with data taken from adjacent areas not affected by ash fall. If these data document the maintenance of terrestrial resources within and following the Middle Polychrome Period, supportive evidence of the "volcanic fallout" hypothesis is provided, and

b) Analysis of sites adjacent to fresh water and substantial estuaries within the area of ash fall is necessary in estimating the magnitude of the impact of the eruption on these theoretically vulnerable resources.

5) More extensive research on site distributions of different time periods is vital. Of concern here are distribution analyses of sites located on the windward versus leeward sides of suspect volcanos, as well as improving the overall inland site data base.

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TABLE I

	1/4" Screen								1/2" Screen							
	Early		Early Middle		Late Middle		Early		Early Middle		Late Middle		Late			
	Polychrome		Polychrome		Polychrome		Polychrome		Polychrome		Polychrome		Polychrome			
	MNI	(%)	MNI	(%)	MNI	(%)	MNI	(%)	MNI	(%)	MNI	(%)	MNI	(%)		
Pelagic Reef/Rock	2	( 6%)	13	(15%)	101	(35%)	7	(47%)	16	(36%)	63	(75%)	42	(82%)		
	3	( 8%)	10	(12%)	21	( 8%)	0	( 0%)	6	(14%)	3	( 4%)	2	(4%)		
Estuary	5	(14%)	6	( 7%)	8	( 3%)	0	( 0%)	3	( 7%)	2	( 2%)	0	(0%)		
Estuarine Tendency	5	(14%)	12	(14%)	16	( 6%)	2	(13%)	8	(18%)	1	( 1%)	1	( 2%)		
Caranx	4	(11%)	15	(18%)	42	(15%)	2	(13%)	2	( 5%)	3	( 4%)	2	( 4%)		
Miscellany	14	(39%)	12	(14%)	24	( 9%)	3	(20%)	6	(14%)	9	(11%)	3	( 6%)		
<i>(Diodon)</i>	(11)	(31%)	(6)	( 7%)	(10)	( 3%)	(2)	(13%)	(3)	( 7%)	(3)	( 4%)	(2)	( 4%)		
Unid. Fish	3	( 8%)	17	(20%)	66	(24%)	1	( 7%)	3	( 7%)	3	( 4%)	1	( 2%)		
	MNI	(Total bones)	MNI	(Total bones)	MNI	(Total bones)	MNI	(Total bones)	MNI	(Total bones)	MNI	(Total bones)	MNI	(Total bones)	Fish Totals	
Unid. Fish	3	(117)	17	(599)	66	(2774)	1	(27)	3	(104)	3	( 96)	1	( 31)	94 (3748)	
I.D. Fish	33	(232)	68	(986)	212	(5182)	14	(52)	41	(220)	81	(381)	50	(295)	499 (7348)	

**TABLE II**  
**Ecological Groupings of Identified Fish**

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Pelagic

*c.f. Euthynnus lineatus*  
*Auxis sp.*

Reef/Rock

*Cymnothorax sp.*  
*Epinephelus sp.*  
*Lutjanus argentiventris*  
*Macmulon sp.*  
*Bodianus sp.*  
*Bodianus diplotaenia*  
*Halichoeres sp.*  
*Scarus sp.*  
Balistidae  
*Balistes sp.*  
*Pseudobalistes naufragium*

Estuary, Brackish Water, Mud Substrate

*Bagre sp.*  
*Ariopsis sp.*  
*Lepisosteustropicus*  
Eleotridae *c.f. Eleotris picta*  
Batrachoideidae *c.f. Daector sp.*  
*Centropomus sp.*

Tending towards Estuarine Environments (but which also occur in other inshore habitats, e.g., sandy substrates)

*Dasyatis sp.*  
*Negaprion fronto*  
*Carcharhinus leucas*  
*Elops affinis*  
Siluriformes  
*Vomer declivifrons*  
*Selene sp.*  
*Lutianus sp.*  
*Mugil sp.*  
*Sphoeroides sp.*

*Caranx sp.*

*Caranx sp.*  
*Caranx caballus* (inshore and pelagic)  
*Caranx hippos* (inshore and pelagic)

Miscellaneous

- I. Inshore vegetation/sandy substrates  
*Calamus brachysomus*
- II. Inshore and pelagic habitats  
Belonidae  
*Tylosurus sp.*  
*Sphyraena sp.*  
*Scomberomorus sierra*
- III. Inadequate identifications for habitat grouping purposes  
Rajiformes  
Squaliformes  
*Diodon sp.*  
*Anisotremus sp.*
- IV. Tentative identifications  
*c.f. Acanthuridae*  
*c.f. Gerres cinereus*  
*c.f. Selene*  
*c.f. Trachurus*  
*c.f. Pogonias*  
*c.f. Scorpaena*

**TABLE III**  
**'Terrestrial Fauna' used in the Text**

	Reptilia MNI (No.)	Aves MNI (No.)	Mammalia MNI (No.)	Total Terrestrial Fauna MNI (No.)
<i>1/4" Samples</i>				
Early Polychrome	4 ( 44) iguanids 3 ( 6) snakes 2 ( 5) Turtles	1 (1) Currasow	2 ( 70) deer 1 ( 3) peccary 1 ( 1) fox 1 ( 2) raccon	15 (132)
Early Middle Polychrome	6 (133) iguanids 1 ( 4) turtle 2 ( 29) snakes	1 (1) <i>Crax</i> 1 (2) bobwhite	1 ( 1) jaguar 1 ( 1) rabbit 3 (119) deer 1 ( 4) raccoon 1 ( 14) armadillo 2 ( 5) squirrel 1 ( 10) peccary 1 ( 1) opossum	22 (325)
Late Middle Polychrome	4 (135) iguanids 1 ( 1) <i>Ameiva</i> 3 ( 40) turtles 4 ( 37) snakes		4 (160) deer 2 ( 3) opossum 2 ( 4) peccary 1 ( 37) armadillo 1 ( 5) rabbit 1 ( 2) raccoon 1 ( 3) squirrel	24 (427)
<i>1/2" Samples</i>				
Early Polychrome	1 ( 7) iguanid 1 ( 4) turtle		2 ( 26) deer 1 ( 1) opossum	5 ( 38)
Early Middle Polychrome	5 ( 53) iguanids 2 ( 28) turtles 1 ( 1) snake		5 (138) deer 2 ( 10) peccary 1 ( 2) brocket deer 1 ( 1) raccoon 1 ( 2) armadillo 1 ( 1) rabbit	19 (236)
Late Middle Polychrome	2 ( 11) iguanids 1 ( 3) snake 1 ( 8) turtle		3 (110) deer 2 ( 8) opossum 1 ( 2) peccary 1 ( 2) armadillo 1 ( 1) <i>Agouti</i>	12 (145)
Late Polychrome	1 ( 1) iguanid		2 ( 61) deer 1 ( 1) peccary 1 ( 1) tapir	5 ( 64)

TABLE IV

## Ratios of Tuna and Deer Bone, by screen size and time period

	Deer MNI	Deer Total No. Bones	Tuna MNI	Tuna Total No. Bones	Tuna MNI: Deer Total No. Bones
Early Polychrome					
1/4"	2	70	2	36	1:35
1/2"	2	26	7	37	1:4
composite		96	9		1:10.7
Early Middle Polychrome					
1/4"	3	119	12	400	1:9.9
1/2"	5	138	15	121	1:9.2
composite		257	27		1:9.5
Late Middle Polychrome					
1/4"	4	160	99	3143	1:1.6
1/2"	3	110	62	303	1:1.8
composite		270	161		1:1.7
Late Polychrome					
1/2"	2	61	42	269	1:1.5

TABLE V

## Terrestrial Fauna/Total Fish Ratios for 1/4" Screen

	Terrestrial Fauna MNI	Total Fish MNI	
Early Polychrome	15:36	1:2.4	
Early Middle Polychrome	22:85	1:3.9	1.6 fold increase
Late Middle Polychrome	24:278	1:11.6	3.0 fold increase

TABLE VI

## Terrestrial Fauna/Pelagic Fish Ratios (1/4")

	Terrestrial Fauna MNI	Pelagic Fish MNI	
Early Polychrome	15:2	7.5:1	4.4 fold increase
Early Middle Polychrome	22:13	1.7:1	7.1 fold increase
Late Middle Polychrome	24:101	1:4.2	

**TABLE VII**  
**Terrestrial Fauna/Non-Pelagic Fish Ratios (1/4")**

	Terrestrial Fauna MNI	Non-Pelagic Fish MNI	
Early Polychrome	15:34	1:2.3	1.4 fold increase
Early Middle Polychrome	22:72	1:3.3	2.3 fold increase
Late Middle Polychrome	24:177	1:7.4	

**TABLE VIII**  
**Terrestrial Fauna/Estuarine, Estuarine Tendency  
 Fish Ratios (1/4")**

	Terrestrial Fauna MNI	Estuarine Fish Groups MNI	
Early Polychrome	15:10	1:.67	1.2 fold increase
Early Middle Polychrome	22:18	1:.82	1.2 fold increase
Late Middle Polychrome	24:24	1:1.0	

**TABLE IX**  
**Terrestrial Fauna/Total Fish Ratios for 1/2" Screen**

	Terrestrial Fauna MNI	Total Fish MNI	
Early Polychrome	5:15	1:3.0	1.3 fold decrease
Early Middle Polychrome	19:44	1:2.3	3.0 fold increase
Late Middle Polychrome	12:84	1:7.0	1.5 fold increase
Late Polychrome	5:51	1:10.2	

**TABLE X**  
**Terrestrial Fauna/Pelagic Fish Ratios (1/2")**

	Terrestrial Fauna MNI	Pelagic Fish MNI	
Early Polychrome	5:7	1:1.4	1.7 fold decrease
Early Middle Polychrome	19:16	1.2:1.0	6.25 fold increase
Late Middle Polychrome	12:63	1:5.25	1.6 fold increase
Late Polychrome	5:42	1:8.4	

**TABLE XI**  
**Terrestrial Fauna/Non-Pelagic Fish Ratios (1/2'')**

	Terrestrial Fauna MNI	Non-Pelagic Fish MNI	
Early Polychrome	5:8	1:1.6	
Early Middle Polychrome	19:28	1:1.5	1.1 fold decrease
Late Middle Polychrome	12:21	1:1.75	1.2 fold increase
Late Polychrome	5:9	1:1.8	1:0 fold increase

**TABLE XII**  
**Terrestrial Fauna/Estuarine, Estuarine Tendency  
 Fish Ratios (1/2'')**

	Terrestrial Fauna MNI	Estuarine Fish Groups MNI	
Early Polychrome	5:2	2.5:1	1.5 fold increase
Early Middle Polychrome	19:11	1.7:1	2.4 fold decrease
Late Middle Polychrome	12:3	4:1	1.25 fold decrease
Late Polychrome	5:1	5:1	

**TABLE XIII**  
**Tetrapod Data Omitted from the Text**

Microfauna (MNI's, and total sample size in parentheses)

	Anura	Small Rodents	Reptiles & Birds	Mammals
<i>1/4'' Samples</i>				
Early Polychrome	1 ( 3)	2 (12)	1 ( 1) turkey ( 4) unidentified	1 ( 2) dog (402) unidentified
Early Middle Polychrome	5 (26)	5 (22)	( 1) <i>Zenaida</i> ( 34) unidentified	2 ( 2) bats ( 1) dog (402) unidentified
Late Middle Polychrome	7 (49)	16 (94)	1 ( 1) <i>Eretmochelys</i> 1 ( 14) turkey 1 ( 1) <i>Penelope</i> 1 ( 1) <i>Zenaida</i> 1 ( 1) <i>Chilodnias</i> 1 ( 1) <i>Botogeris</i> 1 ( 1) Cathartidae 1 ( 1) Accipitridae ( 46) unidentified	1 ( 1) dog 1 ( 1) bat (790) unidentified
<i>1/2'' Samples</i>				
Early Polychrome			1 ( 1) turkey ( 2) unidentified	1 ( 8) dog, juv. ( 58) unidentified

Microfauna (MNI's, and total sample size in parentheses)				
	Anura	Small Rodents	Reptiles & Birds	Mammals
Early Middle Polychrome			1 ( 3) turkey ( 6) unidentified	1 ( 4) dog (215) unidentified
Late Middle Polychrome		1 ( 1)	2 ( 4) turkey ( 8) unidentified	(273) unidentified
Late Polychrome			2 ( 4) turkey ( 6) unidentified	( 78) unidentified
TOTALS	13 (78)	23 (128)	1 ( 1) sea turtle 9 ( 27) turkey 7 ( 7) other birds (106) unidentified	5 ( 16) dog 3 ( 3) bats (2,218) unidentified

### APPENDIX I

#### Species present, by taxa

Class Amphibia				
Order Anura				frogs and toads
Rhinophryniidae				
<i>Rhinophrynus dorsalis</i>				
Bofonidae				
<i>Bufo sp.</i>				
<i>Bufo marinus</i>				
Ranidae				
<i>Rana palmpies</i>				
Class Reptilia				
Order Testudinate				
Kinosternidae				mud turtles
<i>Kinosternon leucostomum</i>				
Cheloniidae				sea turtles
<i>Eretmochelys imbricata</i>				
Emydidae				
<i>Chrysemys ornata</i>				
<i>Rhinoclemmys pulcherrima</i>				
Order Squamata-Lacertilia				
Iguanidae				
<i>Ctenosaura similis</i>				
<i>Iguana iguana</i>				
Teiidae				
<i>Ameiva sp.</i>				
Order Squamata-Serpentes				
Boidae				
<i>Constrictor constrictor</i>				
<i>Epicrates cenchria</i>				
Colubridae				
<i>c.f. Coluber mentovarius</i>				
Viperridae				
<i>Crotalus durissus</i>				
Class Aves				
Order Anseriformes				
Anatidae				ducks
<i>Anas discors</i>				blue-winged teal

Order Falconiformes		
Cathartidae		vultures
Accipitridae		
Order Galliformes		
Cracidae		
<i>Crax rubra</i>		great curassow
<i>c.f. Penelope purpurascens</i>		crested guan
Phasianidae		
<i>Colinus leucopogon</i>		bobwhite, spotted-bellied
<i>c.f. Melleagrism gallopavo</i>		turkey
Order Charadriiformes		
Columbidae		
<i>Zenaida asiatica</i>		pigeons and doves
white-winged dove		
Order Psittaciformes		
Psittacidae		
<i>Botogeris jugularis</i>		macaws and parrots
tovi parakeet		
Class Mammalia		
Order Marsupiala		
Didelphidae		
<i>Didelphis marsupialis</i>		black-eared opossum
Order Chiroptera		
<i>c.f. Phyllostomatidae</i>		bat
Order Primates		
Hominidae		
<i>Homo sapiens</i>		humans
Order Edentata		
Dasypodidae		
<i>Dasyus novemcinctus</i>		9-banded armadillo
Order Lagomorpha		
Leporidae		
<i>Sylvilagus floridianus</i>		cottontail
Order Rodentia		
Sciuridae		
<i>Sciurus sp.</i>		squirrel
Heteromyidae		
<i>c.f. Liomys salvini</i>		spiny pocket mouse
Cricetidae		
<i>c.f. Peromyscus nudipes</i>		white-footed mouse
<i>Sigmodon hispidus</i>		cotton rat
Dasyproctidae		
<i>Dasyprocta punctata</i>		agouti
Order Carnivora		
Canidae		
<i>Canis c.f. familiaris</i>		domestic dog
<i>Urocyon cinereoargenteus</i>		grey fox
Procyonidae		
<i>Procyon lotor</i>		raccoon
Felidae		
<i>Felis onca</i>		jaguar
Order Perissodactyla		
Tapiridae		
<i>Tapirus bairdii</i>		tapirs
Order Artiodactyla		
Tayassuidae		
<i>Tayassu tajacu</i>		peccary
<i>Tayassu c.f. pecari</i>		collared peccary
white lipped peccary		
Cervidae		
<i>Odocoileus virginianus</i>		white-tailed deer
<i>Mazama americana</i>		brocket deer